

Development of a 3-D impedance tomography

Hasan N. Oguz

Department of Mechanical Engineering

The Johns Hopkins University

410-516-4651

410-516-7254 (FAX)

oguz@jhu.edu

Award: N00014-97-1-0982

Long-term goals

The long-term goals of this project are to determine the feasibility of detecting objects or inclusions in a uniform medium by using a 3-D impedance tomography, to verify its applicability experimentally, and to establish the limitations of the proposed technique.

Objectives

The object of this project is to develop a 3-D impedance tomography system by which spheroidal objects can be imaged from boundary measurements in a uniform conductive target space. This is a fundamental numerical study as an attempt to extend a successful 2-D algorithm to 3-D. The determination of the stability and robustness of this imaging algorithm is of primary importance.

Approach

In a typical impedance tomography, a certain voltage distribution is applied to suitably placed electrodes in a target space and a conductivity map of the target is obtained from measured currents at the electrodes. Typical images obtained by this technique have low resolution and the inversion process is often unstable. The novelty of the proposed technique is based upon the parametric representation of the object shapes and an efficient solution of the forward problem by means of a 3-D boundary integral method. To test its feasibility, a simple model problem is considered in this study. The target space is a cylinder with electrodes placed on its boundary. This arrangement

Report Documentation Page			<i>Form Approved OMB No. 0704-0188</i>	
<p>Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p>				
1. REPORT DATE 30 SEP 1997	2. REPORT TYPE	3. DATES COVERED 00-00-1997 to 00-00-1997		
4. TITLE AND SUBTITLE Development of a 3-D Impedance Tomography		5a. CONTRACT NUMBER		
		5b. GRANT NUMBER		
		5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S)		5d. PROJECT NUMBER		
		5e. TASK NUMBER		
		5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Johns Hopkins University, Department of Mechanical Engineering, Johns Hopkins Rd, Laurel, MD, 20723		8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)		
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited				
13. SUPPLEMENTARY NOTES				
14. ABSTRACT				
15. SUBJECT TERMS				
16. SECURITY CLASSIFICATION OF:		17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified		

is particularly suitable for experimental verification that may be pursued in the future. The electrodes are uniformly distributed in the angular direction and in the z-direction. The main assumptions are

- Electrodes are highly conductive
- Target space has a uniform conductivity
- Targets are spheroidal objects with negligible conductivity. The imaging algorithm requires the following tools

- **Forward solution:** a module which can produce boundary values from the knowledge of the target geometry. It is used to compute the *error*. The modeling of the target, the geometry of the measurement points or electrodes and the design of an efficient solution scheme are the most important components of this task.
- **Error minimization:** A module that minimizes the *error* computed by the forward solution by adjusting the target geometry. For this task, the MINPACK software package is utilized.

An iterative imaging algorithm is utilized. The steps involved in this algorithm are

- (0) Start with an initial target shape
- (1) Compute the currents at the electrodes (forward solution)
- (2) Calculate the error, i.e. the difference between the computed and measured currents at the electrodes.
- (3) Adjust the parameters of the target shape to reduce the error (minimization)
- (4) Go to (1) if the change is greater than a certain minimum value

Work completed

A computer program incorporating the model described above has been developed and tested. The targets are assumed to be discrete, spheroidal objects. The shape of the target is defined by the equation

$$r = \sum_{m=0}^{M_p} \sum_{n=m}^{N_t} \begin{pmatrix} a_{mn} \\ b_{mn} \end{pmatrix} P_n^m(\cos \theta) \begin{pmatrix} \cos \psi \\ \sin \psi \end{pmatrix} \quad (1)$$

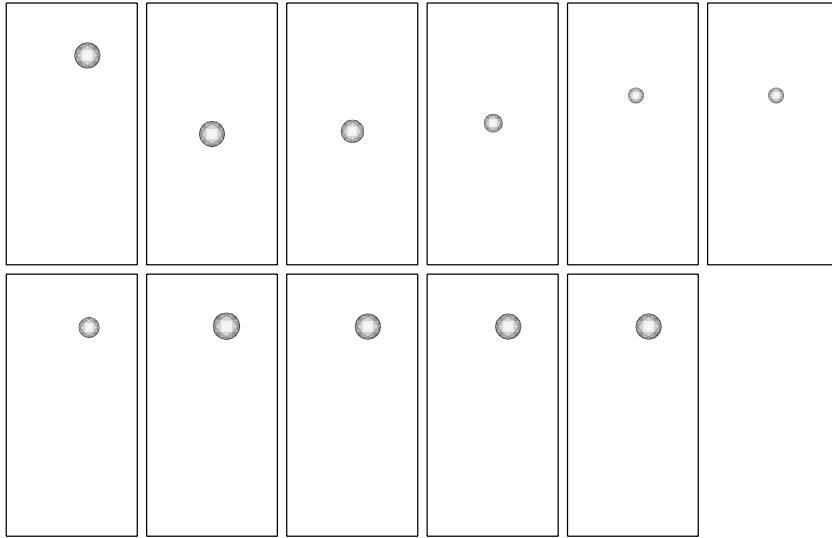


Figure 1: Images of the original sphere (frame 1) and successive iterations of the reconstructed sphere. The target space is a cylinder whose diameter is equal to the width of each frame.

where

$$r = \sqrt{(x - x_0)^2 + (y - y_0)^2 + (z - z_0)^2},$$

θ and ψ are the spherical coordinates with the origin at the center of the target (x_0, y_0, z_0) . The parameters $x_0, y_0, z_0, a_{mn}, b_{mn}$ define the shape of the target. The number of parameters to fully describe a spherical target is four which is also the minimum number of parameters required for a generic target. In the numerical simulations that have been performed so far, spherical targets are used. The results for single spheres are very encouraging. It has been found that a single realization of the electric field produces enough information to image a single sphere. In fig. (1) successive images of a sphere obtained from the iteration procedure are shown. The first frame depicts the original sphere and the last frame the reconstructed sphere. The differences between the two is virtually indistinguishable. In the case of two spheres, good results are obtained when spacing between the spheres is sufficiently large. Again, a single realization of the electric field provides sufficient information to locate two spheres. A typical example is shown in fig. (2) where two spheres that are initially located at the center of the tube converge to the original configuration.

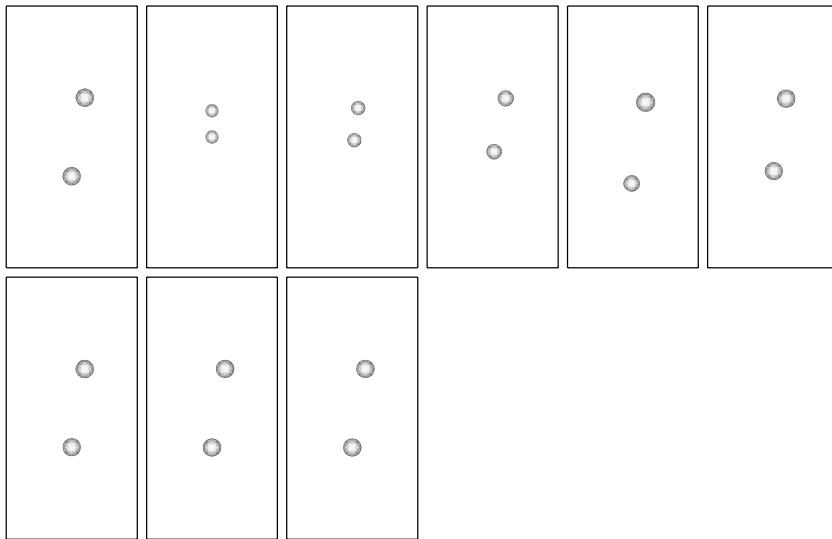


Figure 2: Images of two original spheres (frame 1) and successive iterations of the reconstructed spheres. The target space is a cylinder whose diameter is equal to the width of each frame.

Results

The initial set of numerical simulations indicate that single spheres can be imaged with a single realization of the electric field. Remarkably, spheres far from the electrodes can also be detected accurately. The algorithm works in the case of two spheres if the spheres are sufficiently apart. Further tests are needed to determine the performance of the algorithm for multiple spheres and other shapes.

Impact/Applications

The usage of the electrical impedance tomography has been limited because of poor image quality and instability of the inversion process in the past. If these problems can be overcome by the proposed technique that restricts the target shape to certain basic types, applications where non-intrusive detection of voids is needed can greatly benefit from this research.

Transitions

N/A.

Related Projects

N/A.

References

N/A.